International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN (P): 2249–6890; ISSN (E): 2249–8001
Vol. 10, Issue 1, Feb 2020, 13–20

METHODOLOGY FOR ASSESSING THE RISKS OF EMERGENCIES ON THE EAST SIBERIA - PACIFIC OCEAN OIL AND GAS MAIN PIPELINE

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ABSTRACT

The object of the study was the main pipeline in East Siberia - Pacific Ocean. The main pipeline works in difficult conditions, therefore the assessment of the risks of accidents is absolutely necessary. The combined risk assessment method consisting of the Checklist expert evaluation and the Fault Tree was used in the article. The Fault Tree sample was suggested for described case study. The standard Checklist questionnaire was revised and expanded from 10 to 50 questions, to get more accurate accidents' risk assessment. The scenario of pipeline depressurization frequencies was also considered. The actual emergencies and incidents registration form was proposed. The ranking of main pipeline sections by accident rate was carried out. The software for systematization risk assessment data and accurate accident predictions is planned to be created during further research.

KEYWORDS: Risk Assessment, Checklist Method, Fault Tree Method, Main pipelines, Oil & Gas Transportation

Received: Aug 24, 2019; **Accepted:** Sep 14, 2019; **Published:** Jan 10, 2020; **Paper Id.:** IJMPERDFEB20202

Original Article

1. INTRODUCTION

Pipe line transportation is the cheapest and most reliable way to deliver oil and gas to consumers [Stephenson and Agnew, 2016]. East Siberia – Pacific Ocean (ESPO) main pipeline with a length of 4740 m is an important way to deliver fuel to Asian and American consumers [Abramov et al., 2018; Gulakova et al., 2018; Vatansever, 2017]. The ESPO main pipeline route runs through an area, characterized by harsh environmental conditions, including complex engineering-geological, hydrological, geodynamic and seismic conditions. An accident at any ESPO facility can result in severe economic, environmental and social losses.

Various accidents and emergencies can occur during the transportation of hydrocarbons, oil and gas through pipelines [Bujok et al., 2018; Klimova, 2017]. Currently, there are a number of methods and techniques for quantitative and qualitative analysis and risk assessment of emergencies on trunk pipelines. The most popular of them are: Check-List, What-If, HAZID, HAZOP, FMECA, FTA, ETA, QRA [Cheraghi et al., 2019; Yuhui et al., 2018; Bai and Bai, 2017].

Each of the existing methods has its own advantages: from the simplicity of the questionnaire assessment [Eskander, 2018], due to expert perception of the state of the pipeline (Check-List, What-If methods), to the use of high-precision state sensors of various operation parameters of the facility with the automated making of appropriate corrections in the presence of deviations in work [Bayramov et al., 2016]. However, all these methods have one common drawback - the lack of a full-fledged ability to assess the specific proportion of accident factors of fundamentally different origin: anthropogenic [Zambrano et al., 2018a], natural [Zambrano et al., 2018b], structural, technological, etc.

2. PROPOSED METHODOLOGY

A quantitative assessment of the risk of accidents includes an assessment of the frequency of possible accident scenarios, and an assessment of the possible consequences of the considered accident scenarios. In this case, the scenario of pipeline depressurization frequencies is considered (Table 1).

Table 1: Pipeline Depressurization Frequencies (from National Guidelines for Risk Assessment at Hazardous Production Facilities)

Inner Diameter, Mm	Depressurization Frequencies, $year^{-1} \cdot m^{-1}$	
	Full Section Gap, Outflow from Two Pipe Ends	Outflow through the Hole
< 75 mm	$1 \cdot 10^{-6}$	$5 \cdot 10^{-6}$
From 75 to 150 mm	$3 \cdot 10^{-7}$	$2 \cdot 10^{-6}$
> 150 mm	$1 \cdot 10^{-7}$	$5 \cdot 10^{-7}$

To analyze the possible causes of an accident at the oil pipeline, a logically organized graphic design is constructed (Figure 1), which demonstrates the interaction of system elements, the failure of which individually can lead to the appearance of an undesirable event. The assessment was carried out using the Fault Tree method. The result of the assessment is the value of the probability (value*p*on the Figure 1) of an emergency that arises for various reasons at oil pipelines. The calculations were made according to the statistics of incidents' occurrence.

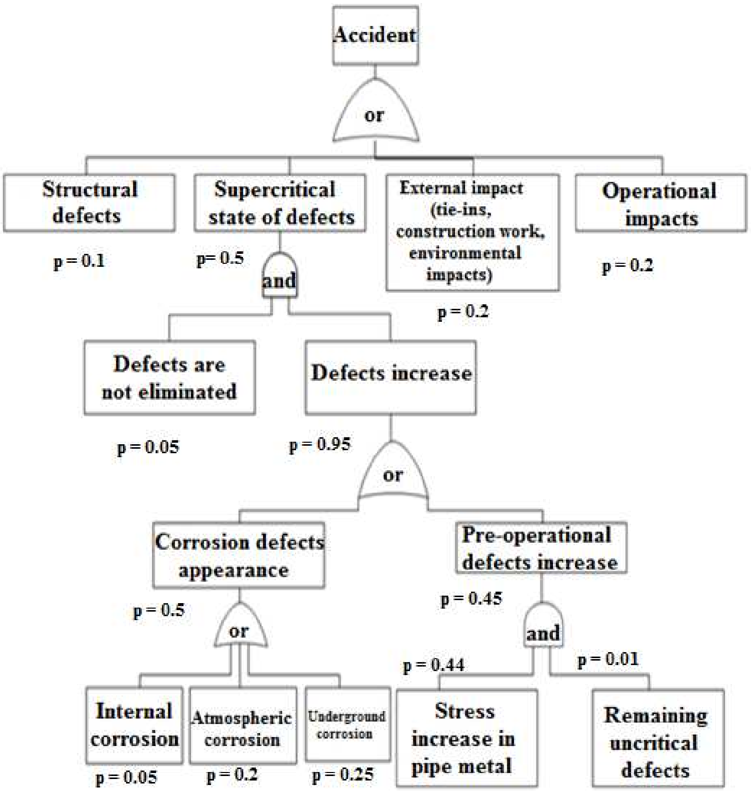

Figure 1: Fault Tree Sample with Probability of Emergencies.

The Figure 1 shows the main factors of emergency situation appearance. The highest probability was assigned to the 'defects increase' point, since in most cases it is a set of defects leading to the development of a major accident.

When assessing the state of the linear part of the main pipelines, experts use qualitative methods based on studying the compliance of the operating conditions of the facilities with the current industrial safety requirements. The most popular is the Check-list method, which consists of 10 basic questions.

The questions used are often general, the answers to which are not able to fully reflect the actual degree of risk of accidents.

In order to prevent the impact of hazardous situations at the fuel and energy complex, it is proposed, adapted to Russian realities, the Check-List album questionnaire, a fragment of which is presented in Table 2. Questions are created on the basis of national safety standards and rules for trunk pipelines.

Table 2: The Sample of the Checklist Questionnaire

Sl. No.	Parameter	Yes	No
1	There are natural and/or artificial barriers on the linear part of the pipeline		
2	There are technological communication and power lines on the linear part of the pipeline		
3	There are along-route and access roads near the section of the linear part of the pipeline		
4	There are protective structures on the linear part of the pipeline		
5	There are bends to end consumers on the linear part of the pipeline		
6	There are water and condensate collectors on the linear part of the pipeline		
7	There are electrochemical protection systems on the linear part of the pipeline		
8	There is an emergency supply of pipes on the linear part of the pipeline		
9	There are houses of linear repairmen-signalmen on the linear part of the pipeline		
10	Pipes are welded		
11	Pipe diameter exceeds 800 mm		
12	There are lack of fusion and weld cracks		
13	Deviation from the nominal sizes exceeds the given / admissible values		
14	Ovality of pipe ends exceeds 1%		
15	The curvature of the pipes exceeds 1.5 mm per 1 m of length		
16	Total pipe curvature exceeds 0.2% of pipe length		
17	Pipe length within 10.5-11.6 m		
18	Visual inspection of the pipeline revealed external defects (cracks, rolling laps, delaminations)		
19	There is delamination at the ends of the pipes and in the area of 25 mm from the ends of the pipes		
20	Welded pipe joints have a smooth transition from the base metal to the weld metal without defects		
21	The ends of the pipes are cut at right angles and have a section for welding		
22	Pipes were tested successfully by hydrostatic pressure at the factory		
23	Welds were tested with non-destructive physical inspection methods		
24	Pipeline monitoring is carried out in a timely manner		
25	Scheduled repairs, interrepair maintenance and scheduled inspection are carried out		
26	Shapes and sizes of the seam are broken		
27	The pipeline is laid underground		
28	The pipeline is laid above the ground		
29	The pipeline is laid under water		
30	Soil has a direct effect on the linear part of the main pipeline		
31	The pipeline is affected by high / low temperature		
32	Flaw detector detects damage		
33	Plant roots affect the pipeline		
34	The pipeline section is separated from the compressor station		
35	Outside insulation in good condition		
36	The nearest settlements are within a radius of more than 2000m		
37	The pipeline intersects with other pipelines		
38	There is a high soil aggressiveness		
39	Pipeline products are fire hazardous and explosible		
40	Pipeline products are toxic		
41	Pipeline products contribute to corrosion		
42	The working pressure in the pipeline complies with the standards		
43	Electrical safety is provided		
44	Pipeline with a diameter of 1020 mm / 1420 mm		
45	High probability of influence of anthropogenic factor		

46	Outdated equipment is used		
47	Additional anti-corrosion treatment of the pipeline is carried out		
48	Warning systems are present		
49	Protection of hazardous areas is provided		
50	Welds leak test is carried out		

By filling out this checklist for the entire pipeline or for its individual section, the conditional safety level is easily determined by multiplying the number of positive responses by 2. For example, if 40 out of 50 questions have a positive answer, then this means that the conditional safety level of the facility is estimated as 80%.

Emergencies and accidents registration form.

For convenient visualization and further systematization, a modification of the existing methodology for a qualitative risk assessment is required.

Therefore, a form for registration of emergencies and incidents is proposed. The basis is the information of acts of investigation of emergencies and incidents on the section of the main pipeline.

The table is built on the example of accidents in mines registration form. The information on acts of investigation of emergencies and incidents on the section of the main pipeline is taken as the basis (Table 3).

Table 3: An Example of the Actual form of Accounting for Emergencies and Incidents in Individual Sections of Linear Pipelines

Sections of Linear Main Pipeline	Nature of Damage	Cause	Date	Consequences	Emergency Source
7	Weld gap	Corrosion	03.08.15	Oil leak	Technogenic
5	Appearance of cracks	Unauthorized ties	30.06.15	Oil leak	Anthropogenic
3	Pipeline rupture	Railway accident	09.11.14	Oil spill, fire	Anthropogenic
7	Corrosion damage	Chemical exposure of the environment	30.03.15	Oil leak	Natural
8	Pipe defect	Violation of the rules of work	10.02.10	Oil spill	Anthropogenic

Emergency situations at the facility are given more attention than incidents of various origins. Ignoring incidents is unacceptable, since it is their combination that leads to emergencies. Therefore, it is proposed to combine the actual form of accounting for acts of investigation of dangerous situations with the developed Check-List questionnaire to prevent the occurrence of large-scale emergencies on linear trunk pipelines. As a result, a hypothetical form for recording incidents and emergencies is proposed (Table 4).

Table 4: An Example of A Hypothetical form of Accounting for Emergencies and Incidents in Individual Sections of Linear Pipelines

Sections of Linear Main Pipeline	On the Linear Part of The Pipeline There are Artificial / Natural Barriers	on the Linear Part of the Pipeline There Are Technological Communication And Power Lines	There Are Lack of Fusion, Weld Tears	Flaw Detector Detects Damage	There are Warning Systems
1	Yes	No	Yes	Yes	No
2	No	No	No	No	Yes
3	No	Yes	No	No	Yes
4	Yes	Yes	No	No	No
5	Yes	No	Yes	No	No

This registration form greatly facilitates the risk analysis of hazardous production facilities on the methods used at the present stage in Russia. These methodologies prescribe the weight of each specified factors in the risk assessment system. The general conclusion about the emergency danger of the site is made depending on several factors in the aggregate: the probability of occurrence, answers to questions from the Check-list, the conditions of the pipeline, climateconditions, etc.

Thus, the sites are ranked by the level of risk of emergencies. On the example of the ESPO-1 and ESPO-2 oil pipelines, on the map of their location (Fig. 2), the checked sections are schematically marked, in the analysis of which natural, technological, and anthropogenic factors are taken into account.

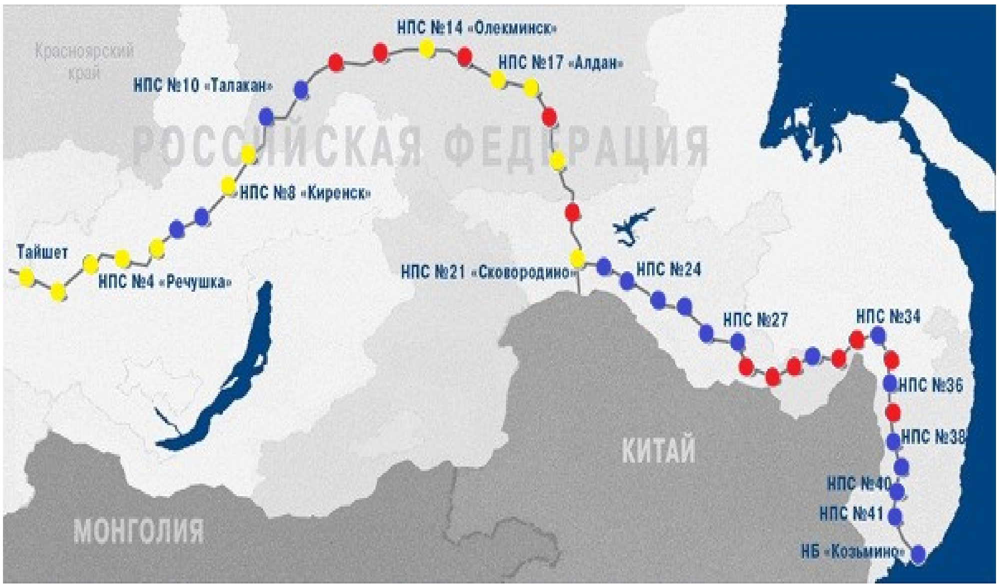

Figure 2: Ranking Sections of Trunk Pipelines by Accident Rate.

The calculation of the sites was made on the basis of the results of an expert assessment of the specialists of the Mining University, who evaluated these sites in accordance with the National methodological recommendations [РД 03-418–01]. Blue areas indicate where the total risk score was less than 0.4, yellow - from 0.4 to 0.6. In red -more than 0.6.

3. CONCLUSIONS

This research was conducted to improve methodological approaches to the qualitative and quantitative analysis of the risk of main pipelines operation, namely: the development of sample questionnaires for creating the Check-List album, the development of recommendations on the use of quantitative methods for assessing the risks of emergencies at Russian facilities of the fuel and energy complex.

The pipeline depressurization frequencies were considered. The Fault Tree sample form was proposed, which could be successfully used for risk assessment of ESPO main pipeline damages. The suggested accidents registration form was used for emergency hazard estimation of the sections of ESPO main pipeline.

The proposed methodological approaches to assessing the risk of operation of trunk pipelines can be used to create a unified automatic database for predicting and recording incidents and accidents at the fuel and energy complex. In the future, it is planned to make a program that will systematize the data, which will most accurately reflect the values of risk indicators for complex technical systems.

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